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# Increasing Information Flow between PDCs

## Objective:

The goal is to be able to receive, on a local PDC, all the phasor data collected by a remote PDC. For a fully configured PDC, this means 16 PMUs, with 10 phasors per PMU for a total of 160 phasors. For a fully configured expanded PDC, this means 32 PMUs, with 10 phasors per PMU for a total of 320 phasors.

## Current State:

At present, the PDCxchng protocol (used by PDCs to exchange data) allows for 2 phasors per PMU to be exchanged. In addition, due to bandwidth limitations, information from a maximum of 9 PMUs may be exchanged.

## Solution Requirements – Protocol:

Any solution that enables full data exchange between PDCs must incorporate a protocol that allows for full data exchange. This could be a redesign of the PDCxchng protocol; the protocol could be extended to allow for sending and receiving a complete data set from fully configured PDCs and PMUs, though the connection would have to utilize a higher bandwidth technology than a telephone line. Another possibility is to modify the PDCstream protocol to allow a PDC to accept the data from another PDC. A third option is to design another protocol from scratch.

## Solution Requirements – Bandwidth:

Accommodating the increased data flow will require the use of a communications interface on the PDC with sufficient bandwidth. At the moment, the only communications interface that exists on the PDC that has sufficient bandwidth is Ethernet. According to the diagram on page 3 of the "Summary Description of the BPA Phasor Data Concentrator" document, the PDC has one Ethernet interface per CPU card. At the moment, one interface is used for communication with PCs on the control LAN and the other provides operators with a data stream via the UDP/IP PDCstream protocol. The bandwidth requirement for PDCstream for a fully configured, expanded PDC is 506,880 bits/sec. (see Appendix A: Data Rates). This is well within the capabilities of Ethernet, even if multiple data streams are used. For example, a local network could consume a data set delivered over PDCstream, while a second data set was sent to a remote PDC over a Wide Area Network (WAN). Ethernet could accommodate both data streams simultaneously. In the event that enough data streams were required that the Ethernet network was in danger of congestion, the problem might be mitigated by substituting an Ethernet switch for the Ethernet hub currently in use. This would not mitigate problems associated with trying to get more than 10Mbit/sec of data out of the PDC on one Ethernet port, but using a switch will reduce problems associated with connecting multiple devices to a single Ethernet segment. Additional considerations exist for sending data over wide area links – these are detailed in the next section.

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### Wide Area Communications and Security

In order to increase the data rate above that available with the PDCxchng protocol, the emphasis in wide area communications must shift away from modems and telephone lines. This shift will require use of a different communications infrastructure, with additional procurement and training costs. Several options exist for high-speed wide area communications, including Frame Relay, Switched Multimegabit Data Service (SMDS – this is T1, T3, etc), Digital Subscriber Line (DSL), Asynchronous Transfer Mode (ATM) and Synchronous Optical Network (SONET). Wide area communications introduce additional variables. For example, depending on the distance to be covered and the capabilities of the communications infrastructure, the data from a remote PDC will be delayed for some amount of time. Use of higher-bandwidth communications channels can mitigate some of this latency, but this drives up costs. Reliability is another issue, since the communications infrastructure for an electric utility must be held to high standards. Simply requesting a DSL connection from the local provider may not provide the robustness required to control the power grid during a disturbance.

Wide area networking also changes the environment for the networking protocols used to deliver data. UDP/IP functions very well in a LAN environment (e.g. PDCstream) but will require that the wide area communications infrastructure be engineered to avoid congestion, as UDP does not guarantee reliable data transport. A possible solution to this is to use TCP for delivering data to remote PDCs. However, this can result in delays during retransmission of lost packets. The answer to this question will come from several places, including the costs of different wide area communications architectures, importance to operators of data timeliness vs. data completeness, and the costs of different modifications to the PDC to support the various options available.

Security requirements also change in the wide area. While it may be tempting to use a Virtual Private Network or similar means to save costs by routing data over the Internet, this opens the network up to denial of service, data corruption, and other attacks. Dedicated circuits are more expensive, but the added security obtained by not allowing a potential attacker to communicate with the network infrastructure at all is well worth the added cost.

## Real Time Control:

In the future, there may be a requirement for the capability to control a PDC or PMU remotely over the same communications infrastructure that is used to deliver the phasor data to the operators. This control data, as well as any other data that may be required from a PDC in the future, must not overload the communications infrastructure. While Ethernet has 10,000,000 bits/sec (10 Mbits/sec) of theoretical bandwidth, that figure is reduced to roughly 4 Mbits/sec because of collisions on a shared Ethernet segment. Collisions can be reduced by using Ethernet switches instead of hubs, but care must be taken not to oversubscribe a single Ethernet port.

In terms of wide area networking, there are several issues that must be considered for real-time control. These include latency (the delay between an operator issuing a command and the command being executed by the remote hardware), congestion (the communications infrastructure must be able to handle the traffic load during a crisis as well as during normal operations) and security. Above all, access to the network that carries control traffic must be restricted to authorized users, and the network infrastructure must be protected from attack. The high standards of security and reliability required will very likely limit the set of technologies and solutions available.

# Appendix A: Data Rates

A fully loaded PDC has 16 or 32 PMU inputs (8 inputs per CPU board, 2 CPU boards currently, and 4 CPU boards if the PDCs are expanded).

A fully configured PMU (10 phasors, 2 digital status words) gives a sample size of 64 bytes. Since we sample at a rate of 30 samples per second, we get the following:

| | |
|---|---|
| PMU with 10 phasors, 2 digital status words: | 64 bytes/sample |
| | x 30 samples/second |
| | = 1,920 bytes/sec |
| | x 8 bits/byte |
| | **= 15,360 bits/sec/PMU** |
| Total phasor data (current PDCs): | 15,360 bits/sec/PMU |
| | x 16 PMUs |
| | **= 245,760 bits/sec** |
| Total phasor data (expanded PDCs): | 15,360 bits/sec/PMU |
| | x 32 PMUs |
| | **= 491,520 bits/sec** |

Note that this takes into account the **phasor data only**. Any data exchange protocol will add protocol overhead, perhaps at several layers. For example, the PDCstream protocol has overhead for Ethernet, IP, UDP and data specific to the PDCstream protocol. This overhead and the total bandwidth required are calculated on the next page.

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# Calculation of phasor data bandwidth requirements, including protocol overhead, using PDCstream as an example:

PDCstream is a UDP/IP protocol that is used to transfer PDC data to a PC for analysis. The PDC and PC are connected via Ethernet. Therefore, we take into account the Ethernet frame, the IP packet, the UDP datagram and the PDCstream message header as well as the phasor data in calculating the total bandwidth required. In this example, we assume a "maximum configuration," meaning a fully configured expanded PDC (32 PMU inputs) with each PMU fully configured (10 phasors, 2 digital words).

| | |
|---|---|
| Ethernet frame headers: | 18 bytes/frame |
| | x 8 bits/byte |
| | x 30 frames/sec |
| | = 4,320 bits/sec Ethernet overhead |
| IP packet headers: | 20 bytes/packet |
| | x 8 bits/byte |
| | x 30 packets/sec |
| | = 4,800 bits/sec IP overhead |
| UDP datagram headers: | 8 bytes/datagram |
| | x 8 bits/byte |
| | x 30 datagrams/sec |
| | = 1,920 bits/sec UDP overhead |
| PDCstream message headers: | 18 bytes/message |
| | x 8 bits/byte |
| | x 30 messages/sec |
| | = 4,320 bits/sec PDCstream overhead |

| | |
|---|---|
| Phasor data from fully configured PDC: | 491,520 bits/sec |
| Ethernet overhead: | + 4,320 bits/sec |
| IP overhead: | + 4,800 bits/sec |
| UDP overhead: | + 1,920 bits/sec |
| PDCstream overhead: | + 4,320 bits/sec |
| Total bandwidth required: | = **506,880 bits/sec.** |

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